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INTRODUCTION TO ARTHROPODS OF PUBLIC
HEALTH IMPORTANCE. TRAINING GUIDE

Harry D. Pratt, et al

Communicable Disease Center
Atlanta, Georgia

1960

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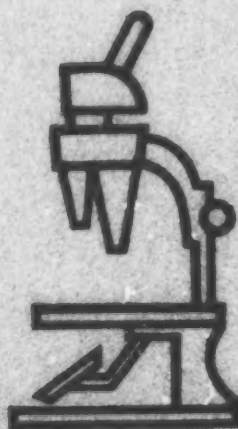
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**INTRODUCTION TO
ARTHROPODS
OF PUBLIC HEALTH IMPORTANCE**



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**U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE**

INTRODUCTION TO ARTHROPODS OF PUBLIC HEALTH IMPORTANCE

TRAINING GUIDE - INSECT CONTROL SERIES

Harry D. Pratt - Kent S. Littig - Clarence W. Marshall



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on microfiche.

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
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Ia



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INTRODUCTION TO ARTHROPODS OF PUBLIC HEALTH IMPORTANCE

INTRODUCTION

Insects are probably the most successful of all land animals. They are found in the air, on and under soil, and in fresh and brackish water. They eat the leaves and roots of plants and bore into all types of vegetation. Some insects live on or inside other animals, and many compete fiercely with other species as parasites, or as predators in preserving the balance in nature. Despite their small size, the combined bulk of insects may equal that of all other land animals. Over 750,000 species of true insects have been described to date, and the number may ultimately reach a million or more.

By contrast Muller and Campbell (1954) estimate that there are about 33,000 living species of Chordata (fishes, amphibians, reptiles, birds, and mammals), of which approximately 3,500 are true mammals. Figure 1.1 illustrates the preponderance of insects in the world fauna. In North America there are an estimated 82,500 described species of insects (U. S. Department of Agriculture, 1952), of which about 10,000 are of economic importance.

For centuries man has fought insects as pests, as carriers of disease, and as destroyers of his food. This combat will continue for a long time to come, for he has never eradicated a single insect species from the earth. Today, a number of the most important species are showing increasingly significant resistance to insecticides. However, when the need is urgent and the will is present to do a good job, insects can be kept under reasonable control.

Insects have a long geological history. They appeared in the world long before man, yet insect fossils from coal and amber deposits differ little

from their present-day descendants despite a lapse of 250 million years or more. As man emerged from geological obscurity, his parasites evolved with him — many of the strictly human parasites such as the body and crab lice having close allies on or in the great apes.

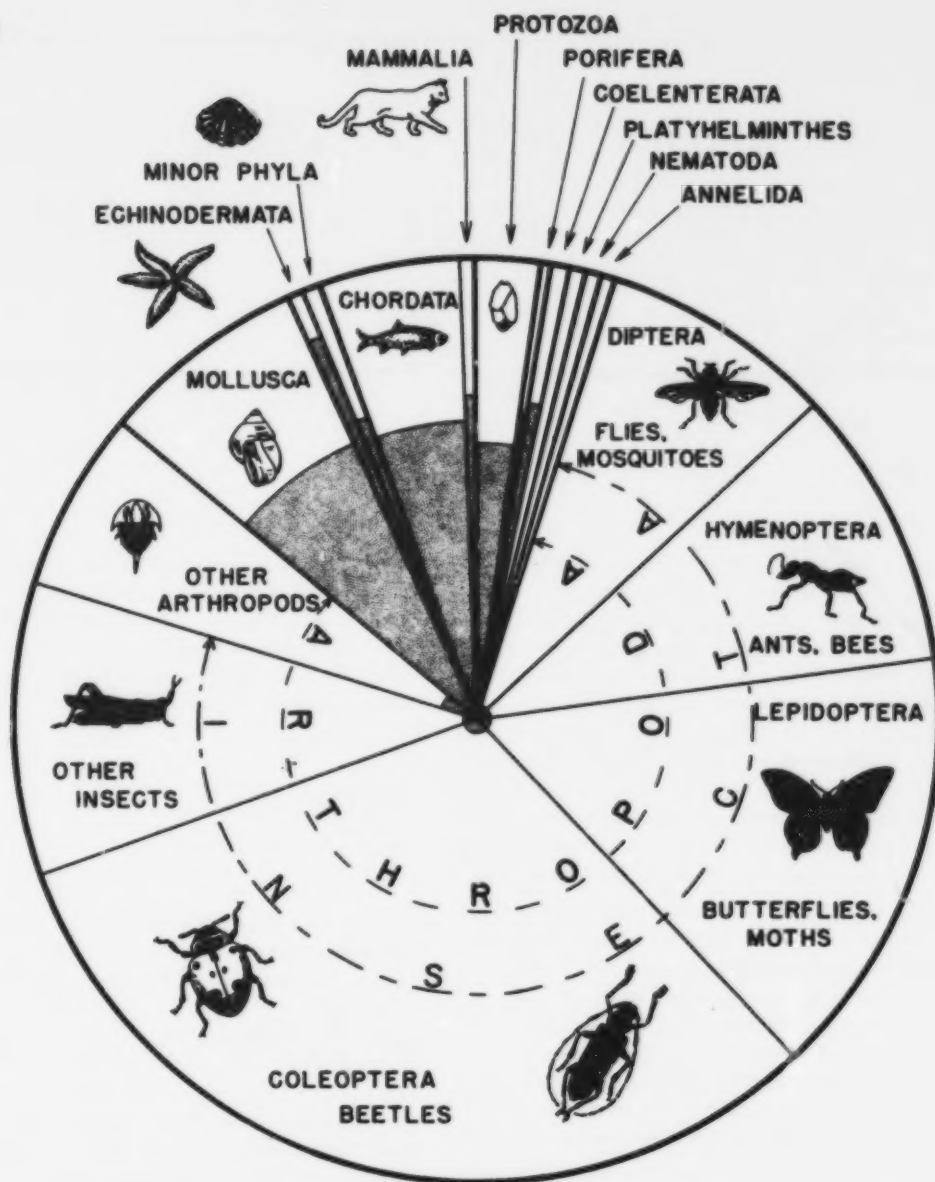
HOW INSECTS AFFECT MAN

Insects are often thought of as man's most formidable competitors. They despoil his growing plants and stored crops; they greedily suck the blood from his body; they annoy him wherever he goes. The damage that insects do to growing crops is enormous. They cost the American farmer billions of dollars each year by destroying or decreasing the value of his crops. Flies, fleas, lice, and mosquitoes infect man and domesticated animals directly or indirectly with the organisms of many dangerous and debilitating diseases.

TRANSMISSION OF HUMAN DISEASE

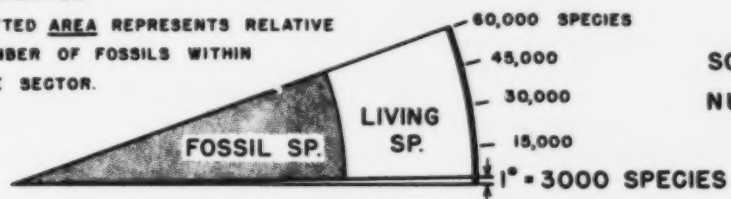
Insect bites or stings are occasionally fatal to humans, but their germ-laden saliva or contaminated bodies may also mark a human victim for death. The most sinister relationship of insects to man and domesticated animals is the part they play as carriers of disease organisms (table 1.1).

Figure 1.1



EXPLANATION:

DOTTED AREA REPRESENTS RELATIVE
NUMBER OF FOSSILS WITHIN
THE SECTOR.



RELATIVE NUMBERS OF KNOWN
SPECIES, LIVING AND FOSSIL,
OF VARIOUS ANIMAL PHyla.

TABLE 1.1 - SOME HUMAN DISEASES TRANSMITTED BY ARTHROPODS IN NORTH AND CENTRAL AMERICA

Disease	Causative Agent	Vector	Method of Infection	Reservoir
Chagas disease	<i>Trypanosoma cruzi</i>	Kissing bugs, <i>Triatoma</i> , and related species	Fecal contamination of bite	Rodents, dogs, cats, etc.
Cholera*	<i>Vibrio cholerae</i>	House fly, <i>Musca domestica</i>	Contamination of foods	Man
Conjunctivitis	<i>Haemophilus aegyptius</i> and others	Eye gnat, <i>Hippelates pusio</i> and related species	Contamination of eye tissues	Man
Dengue*	Virus	Yellow fever mosquito, <i>Aedes aegypti</i>	Bite	Man
Dysentery, Amebic**	<i>Endamoeba histolytica</i>	House fly, <i>M. domestica</i>	Contamination of foods	Man
Dysentery, Bacillary**	<i>Shigella dysenteriae</i> and other species	House fly, <i>M. domestica</i>	Contamination of foods	Man
Encephalitis (St. Louis, Western and Eastern)	Virus	Mosquitoes, <i>Culex tarsalis</i> and others	Bite	Birds and mammals
Filariasis*	<i>Wuchereria bancrofti</i> and possibly <i>malayi</i>	Mosquitoes, <i>Culex</i> , <i>Aedes</i> , <i>Anopheles</i> , and <i>Mansonia</i>	Invasion of bite, also through skin	Man
Leishmaniasis	<i>Leishmania</i> spp.	Sandflies, <i>Phlebotomus</i>	Bite (?)	Man
Malaria	<i>Plasmodium vivax</i> <i>P. falciparum</i> <i>P. malariae</i>	Mosquitoes, <i>Anopheles</i>	Bite	Man
Onchocerciasis	<i>Onchocerca volvulus</i>	Blackflies, <i>Simulium</i>	Invasion of bite	Man
Plague	<i>Pasteurella pestis</i>	Oriental rat flea, <i>Xenopsylla cheopis</i> and other fleas	Bite. Also by contact with infected rodents	Rats and wild rodents

TABLE 1.1 (Continued)

Disease	Causative Agent	Vector	Method of Infection	Reservoir
Relapsing fever	<i>Borrelia</i> spp.	Soft ticks, <i>Ornithodoros</i>	Bite or contamination of bite	Ticks, rodents and other mammals
Rickettsialpox	<i>Rickettsia akari</i>	House mouse mite, <i>Allodermanyssus sanguineus</i>	Bite	House mice
Rocky Mountain spotted fever	<i>Rickettsia rickettsii</i>	Hard ticks, <i>Dermacentor</i> , <i>Amblyomma</i>	Bite	Ticks, Rodents (?)
Tularemia	<i>Pasteurella tularensis</i>	Deerfly, <i>Chrysops</i> Hard ticks, <i>Dermacentor</i>	Bite and contact with infected animal	Rabbits and other wild animals
Typhoid fever**	<i>Salmonella typhosa</i>	House fly, <i>M. domestica</i>	Contamination of food and water	Man
Typhus, Epidemic*	<i>Rickettsia prowazeki</i>	Human body louse, <i>Pediculus humanus</i>	Contamination of bite and abrasions	Man
Typhus, Murine	<i>Rickettsia typhi</i>	Oriental rat flea, <i>Xenopsylla cheopis</i>	Contamination of bite and abrasions	Rats
Yellow fever***	Virus	<i>Aedes aegypti</i>	Bite	Man; monkeys

*Not known in U. S. at present time.

**Disease also spread by other more important carriers.

***Not found in U. S. Prevalent in Central America or Mexico.

Mechanical Transmission of Disease

Mechanical or passive transmission of disease occurs when the insect transports organisms such as dysentery bacteria on its feet, body hairs, and other surfaces from filth to the human. The house fly, *Musca domestica*, is probably the most loathsome passive transmitter of disease. Even in well-housed communities, it is a common sight to see filthy flies crawling over food and utensils and the faces of small children. Scientific studies (Watt and Lindsay, 1948) have shown a close relationship between the incidence of bacillary dysentery and the needless abundance of flies in human habitations. Cockroaches and vinegar gnats are known to visit sewers and liquid excrement, later entering human habitations.

Biological Transmission of Disease

Disease organisms are ordinarily helpless and inactive, being so delicate that they cannot withstand exposure to sunlight and dry air. These organisms would perish with their victim unless there was some means for them to escape from one host and find sanctuary in another. Diseases are spread in many ways, but insects afford one of the most efficient means by which the organisms can infect new hosts. Biological transmission of disease occurs when an insect, mite, or tick is essential in the life cycle of the disease parasite. The *Anopheles* mosquito, for example, is an essential vector in the spread of malaria. The malaria parasite undergoes a portion of its life cycle in both the insect vector and the human host.

Host-Vector Relationships

In considering the insect transmission of disease-causing organisms, it is important to understand the relationships between the vector and the host. The malarial parasites, for example, undergo certain stages of their life cycle in the body of the mosquito. This insect is thus an essential host of the disease, in addition to serving as a carrier or vector. The parasite undergoes the sexual portion of its life cycle in the mosquito, and thus the insect may be considered as the primary or definitive host. On the other hand, the asexual stages of the malarial parasites are passed in man who therefore is the intermediate host.

Disease transmission is often complicated by the presence of more than one host. Some hosts

are not affected by the disease but are able to perpetuate the disease by serving as a safe harbor-age for the organism. These animals are known as reservoirs of the disease. In some cases it is rather difficult to determine whether an animal is the true reservoir of a disease or is the vector alone. Some ticks and mites are able to transmit disease-causing organisms, such as the rickettsiae causing Rocky Mountain spotted fever, to their offspring and thus serve as both vectors and reservoirs of disease. It is possible in this case that other animals, such as wild rodents and rabbits, are actually the true reservoir.

The relationship between man, the insects, and the microorganisms constitutes a great and only partially-solved public health problem. Although malaria and plague have ravaged mankind for thousands of years, the mosquito and the flea vectors were not known until the latter part of the 19th century. Who knows what part insects may play in the transmission of many virus diseases, the host-vector relationships of which are yet to be discovered?

MYIASIS

Myiasis means the infestation of man, or animals, by the living maggots of flies. Some forms, such as bot flies, can breed only in this way. The screw-worm infests livestock in the South and West and occasionally attacks human beings. It is a true parasite living only in the flesh of warm-blooded animals. The larvae of some fly species such as the rat-tailed maggots may be swallowed by humans accidentally, producing intestinal upsets.

POISON, IRRITATION, AND ALLERGY

Many insects, and some spiders, scorpions, and centipedes, have developed poisoning mechanisms to use in self defense or in paralyzing their prey. Stings and bites may be intensely irritating to humans but seldom cause death. Probably the most dangerous are the bites of the black widow spider, *Latrodectus mactans*, and the sting of a small scorpion, *Centruroides sculpturatus* found in the Southwest. Even the stings of bees and wasps may prove toxic to persons allergic to their venoms. Insect venom contains complex protein substances

or formic acid that may lead to anaphylactic shock or death.

Some insects, such as the puss caterpillar, have urticating hairs rather like those of stinging nettles. Cantharidin present in the blood of certain beetles, such as the blister beetles, causes painful blistering of the skin when the insect is crushed. Mosquitoes, sand flies, fleas, and other pestiferous creatures listed in table 1.2 have done much to destroy man's peace of mind. It is necessary for health workers to understand the control of these pests as heavy infestations may affect the health of people and entire communities.

ENTOMOPHOBIA

Entomophobia means fear of insects. Many household pests do little actual harm but arouse intense feelings of revulsion in susceptible people. Crawling creatures, such as earwigs, bother some people so much that medical attention may be necessary. Feelings of repugnance aroused by infestations of insects must be handled with care by the sanitarian as no reasoning will satisfy affected persons. Some definite action such as DDT spraying must be taken to break the chain of circumstances. A moderate feeling of revulsion to insects is of assistance to sanitarians in public health work for it insures the interest of the public in promoting high standards of sanitation.

BENEFICIAL EFFECTS OF INSECTS

It must be emphasized that not all insects are enemies of man. Some, such as the honey bee, are essential to man's existence as efficient pollinators of fruit trees, clover, vegetable crops, and other useful plants. Insect products, such as silk, honey, beeswax, and lac (the basic material for shellac), are products utilized by man. Many insect species are essential to man's welfare because of their part in combating other species that are harmful, maintaining a biological balance in nature. Some serve as predators, feeding upon harmful insects and plants, keeping them under control. Others are parasites of harmful pests and have been used by man in biological control.

Insects should be given some credit for their part in nourishing our most primitive ancestors. Even today human aborigines, such as the Austra-

lian bushmen, subsist in part upon such insects as grubs, grasshoppers and caterpillars.

The fruit fly, *Drosophila*, used as an experimental subject, has contributed much to our knowledge of the study of genetics. Studies on the mechanics of inheritance and on the production of mutations give us insight into this science which has contributed so much to the betterment of man through selective breeding of plants and animals.

THE EXTERNAL STRUCTURE OF INSECTS

At least an elementary knowledge of insect structure is necessary for the correct identification of insects. Insects may be as small as a grain of sand or as large as a doorknob. Shape and color may be an attempt at camouflage, or may go to bizarre extremes for no apparent reason. Size, shape, and color all afford good characters for identification of many species. The "wasp-waist" of the ant, for example, is much different from the broad waist of the termite.

The number of segments into which the body is divided may also serve as a useful character in identification. The most primitive insects, such as the silverfish, possess eleven segments in the abdomen. Most insects have three segments in the thorax, but they vary greatly in size, shape and degree of fusion.

The "skin" of an insect is quite different from the skin of the higher animals. It is, in fact, no skin at all but a more or less stiffened outer skeleton, or *exoskeleton*. It serves as a supporting framework and protective sheath for the insect making it impregnable against minor enemies. The exoskeleton protects the internal systems and organs from injury and serves as a framework for the attachment of muscles. It restricts further growth of the insect once it has hardened, and the insect must molt, or shed its skin, in order to grow larger. The vertebrates are higher animals having a skeleton inside the body which is called the *endoskeleton*. The differences between the two types of skeletal systems are shown in figure 1.2.

Some insects have various parts of the body covering (*cuticula*) hardened or sclerotized. These

TABLE 1.2 - SOME ARTHROPODS AFFECTING HUMAN COMFORT

Common name	Scientific name of arthropod	Effect on man
Mites		
Chigger	<i>Trombicula alfreddugesi</i>	Intense itching; dermatitis
Rat mite	<i>Ornithonyssus bacoti</i>	Intense itching; dermatitis
Grain itch mite	<i>Pyemotes ventricosus</i>	Dermatitis and fever
Scabies mite	<i>Sarcoptes scabiei</i>	Burrows in skin, causing dermatitis
Ticks		
Hard ticks	<i>Amblyomma</i> spp. <i>Dermacentor variabilis</i> <i>D. andersoni</i> and <i>Ixodes</i> spp.	Painful bite Tick paralysis; usually fatal if ticks not removed
Soft ticks	<i>Ornithodoros</i> spp.	Some species very venomous
Black widow spider	<i>Latrodectus mactans</i>	Local swelling; intense pain and occasional death
Scorpions	Order: Scorpionida	Painful sting; sometimes death
Centipedes	Class: Chilopoda	Painful bite
Mayflies	Order: Ephemera	Asthmatic symptoms from inhaling fragments
Caddis flies	Order: Trichoptera	Asthmatic symptoms from inhaling hairs and scales
Lice	<i>Pediculus humanus</i> and <i>Phthirus pubis</i>	Intense irritation, reddish papules
Bugs		
Bed bugs	<i>Cimex lectularius</i>	Blood suckers; irritating to some
Kissing bugs	Family: Reduviidae	Painful bite; local inflammation
Beetles		
Blister beetles	Family: Meloidae	Severe blisters on skin from crushed beetles
Rove beetles	Family: Staphylinidae	Delayed blistering effect
Caterpillars	Order: Lepidoptera	Rash on contact with hairs or spines
Bees, wasps, and ants	Order: Hymenoptera	Painful sting; local swelling
Fleas	Order: Siphonaptera	Marked dermatitis frequent
Flies		
Punkies or Biting midges	<i>Culicoides</i> spp.	Nodular swelling, inflamed
Black flies	<i>Simulium</i> spp.	Bleeding punctures; pain, swelling
Sand flies	<i>Phlebotomus</i> spp.	Stinging bite; itching; whitish wheal
Mosquitoes	Family: Culicidae	Swelling; itching
Horse flies and deer flies	<i>Tabanus</i> spp. and <i>Chrysops</i> spp.	Painful bite
Stable flies	<i>Stomoxys calcitrans</i>	Painful bite

Figure 1.2 (a) Exoskeleton of an arthropod (b) Endoskeleton of a vertebrate

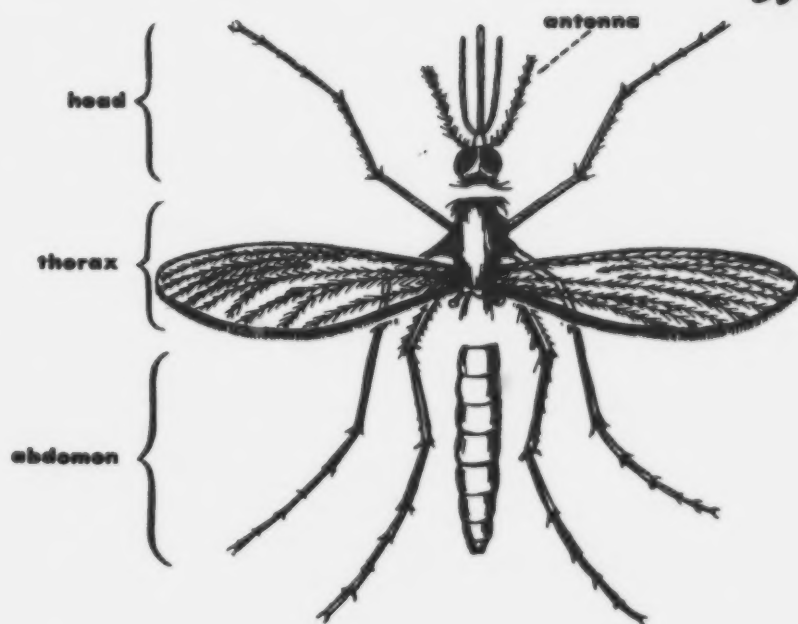
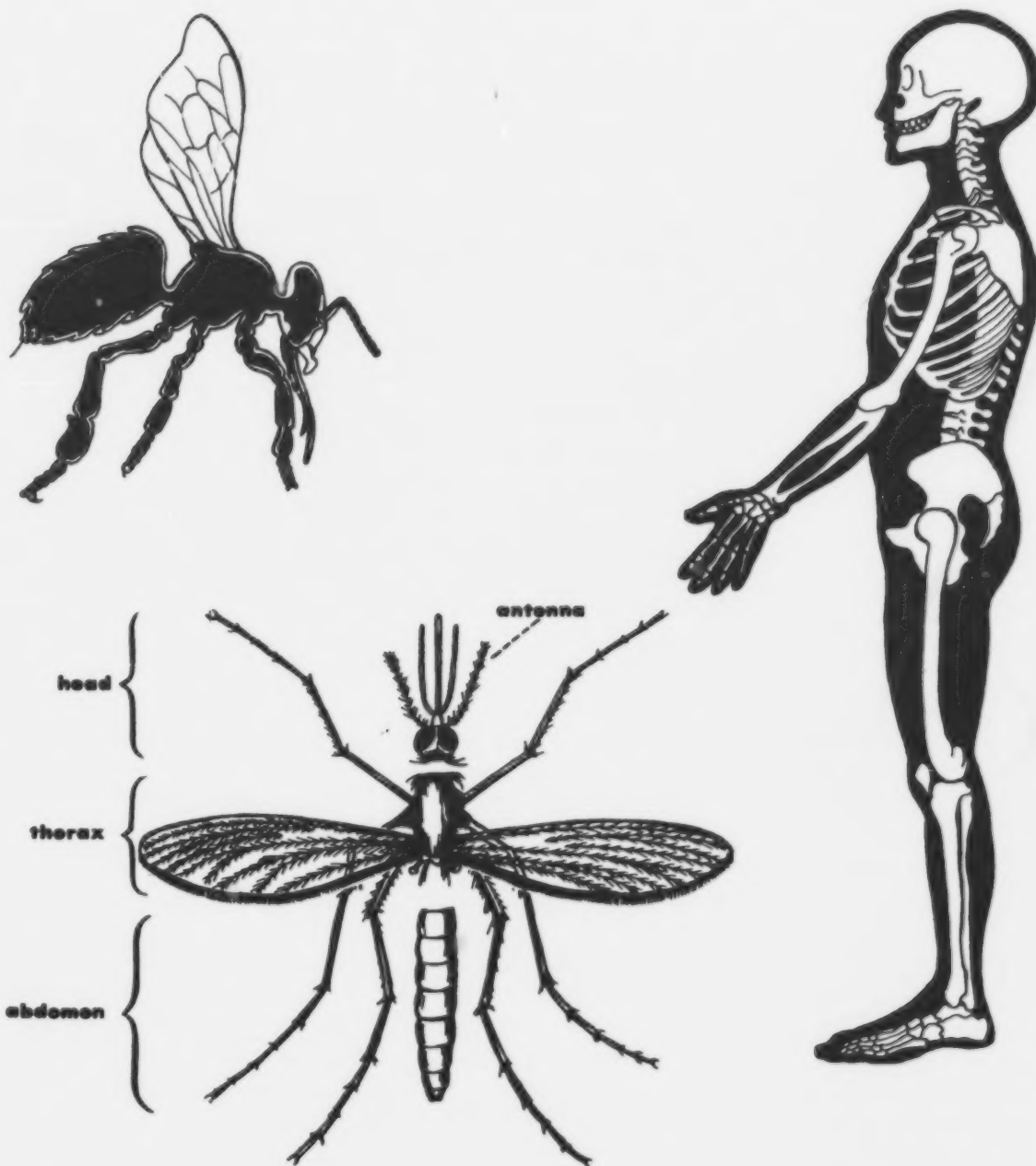


Figure 1.3 Insect (disarticulated) showing body regions

hardened parts are in the form of plates, or sclerites, which are not flexible. Movement of the insect body is made possible by the fact that the sclerites are joined together by flexible portions of the cuticula called *intersegmental membranes*. The abdomen of a mosquito becomes greatly distended during feeding because of the flexibility of these membranous tissues. This is not true growth, however, as the other parts of the exoskeleton are inflexible. The cuticula may be covered with many small structures, such as hairs, scales, protuberances, and spines.

The body of an insect is divided into three principal regions — the *head*, *thorax*, and *abdomen* (fig. 1.3). In the related class *Arachnida*, called *arachnids*, the body is composed of only one or two regions. The *arachnids* are familiar to man as ticks, mites, scorpions, spiders, and harvestmen.

THE INSECT HEAD

The anterior, or first body region, of an insect is known as the head. Its principal appendages (figs. 1.4 to 1.7) are the *mouthparts*, the *antennae*, the large compound eyes, and the simple eyes, or *ocelli*. Adult insects have only one pair of antennae, whereas the *arachnids* have no antennae, and *crustaceans* have two pairs of antennae.

The Mouthparts

The insects have an upper lip, or *labrum*, a pair of *mandibles*, two *maxillae*, and a lower lip, or *labium*. There seems to be an infinite variety of arrangements and forms of these parts, but they may be classified under three principal types: (1) *chewing*; (2) *sponging*; and (3) *piercing-sucking*.

Chewing mouthparts (fig. 1.5) are possessed by insects that grind solid food. The *mandibles* are useful in cutting off food substances, such as the leaves of vegetable crops, and grinding them. The *maxillae*, *labrum*, and *labium* are used in handling this food before it is swallowed. The appendages, known as the *maxillary palpi* and *labial palpi*, assist in the feeding process and are used to taste, smell, and feel food. These appendages bear sensory hairs in which the various senses are concentrated. Some insects have another mouthpart, the tongue-like *hypopharynx*. Most primitive insects, such as the cockroaches and silverfish, possess chewing mouthparts.

Sponging mouthparts (fig. 1.6) are adapted for sucking up liquid or readily soluble foods. These mouthparts have evolved from the more primitive chewing type of mouthpart. The *mandibles* are absent, and the *maxillae* are represented only by their sense organs, the *palps*. The house fly is a typical insect possessing sponging mouthparts. The *labrum* and *labium* have been joined to form a *proboscis* with a spongy tip called the *labellum*. The *proboscis* is thrust into liquid foods, such as milk and feces in order that *capillary grooves* on the face of the *labellum* may carry the liquids to the food canal inside the *proboscis*. Solid foods, such as sugar, may also be eaten if they are readily soluble. The insect regurgitates a drop of saliva on the sugar, causing it to dissolve. The solution is then pumped into the mouth as a liquid. Blow flies, house flies, and flesh flies are unable to bite as they have sponging mouthparts.

Piercing-sucking mouthparts (fig. 1.7) are used to good advantage by mosquitoes, stable flies, sucking lice, fleas, and kissing bugs. Many of the blood-sucking vectors of disease have piercing-sucking mouthparts which are constructed on different basic plans. In some the mouthparts are modified to form a slender beak or *proboscis* which encloses the *stylets*. The sucking lice have no *proboscis*, but the piercing mouthparts are retracted into the head.

The Eyes

Two types of eyes occur in insects . . . simple and compound (fig. 1.4). The simple eyes, or *ocelli* consist of single eye units or *facets*. Three *ocelli* may be arranged in the form of a triangle between the large compound eyes. The compound eyes are usually very large and are round, oval, or kidney-shaped. The outer face of the compound eye is composed of many small six-sided lenses called *facets*. The ant eye has from 50 to 400 *facets*, whereas there may be more than 25,000 *facets* in the dragon fly eye. The size of the eye appears to be related to the demands for accurate vision in the normal life of the insect. In general, the active flying insects have large eyes and many *facets* while the more pedestrian types, such as beetles and ants, have fewer *facets*. Some parasitic insects have poorly developed eyes; or the compound eyes may be absent, as in certain fleas.

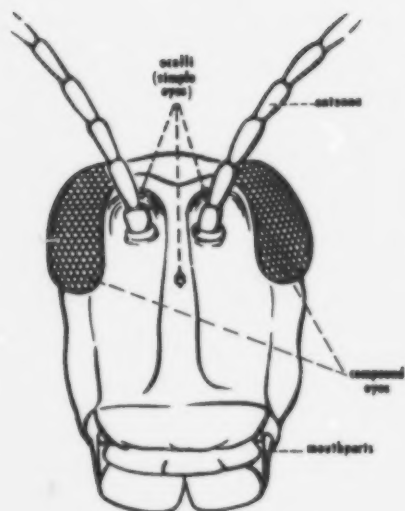


Figure 1.4 Head of an insect showing principal parts

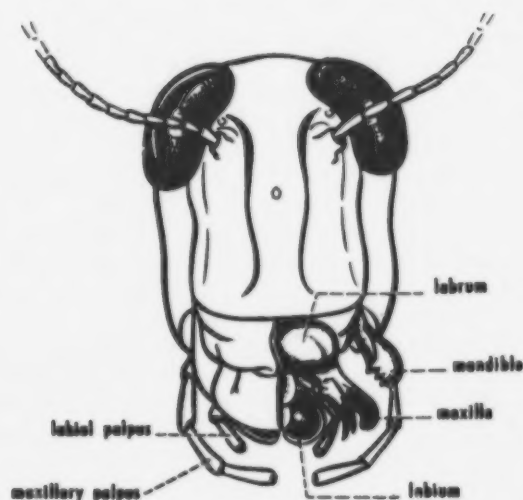


Figure 1.5 Chewing-type mouthparts

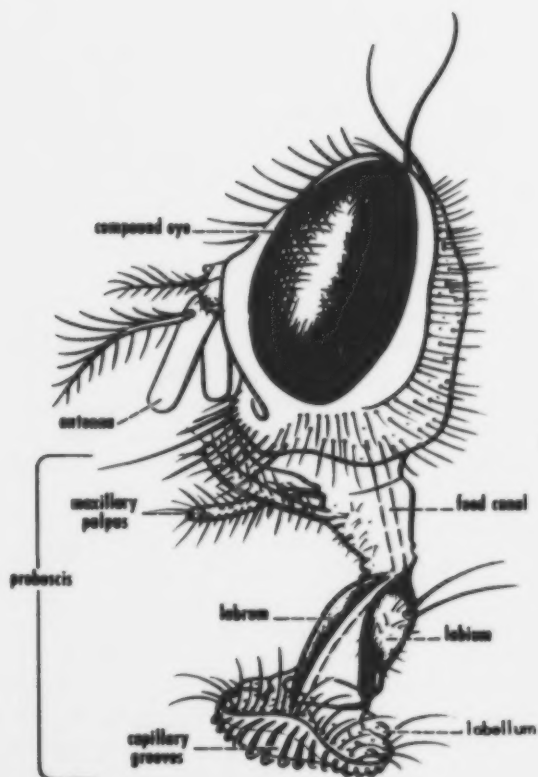


Figure 1.6 Spenging-type mouthparts

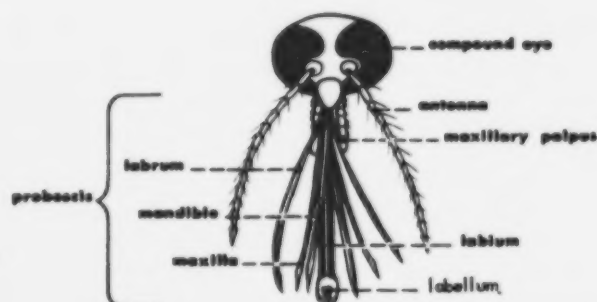


Figure 1.7 Piercing-sucking-type mouthparts

The Antennae

True insects, millipedes, and centipedes, have one pair of antennae, or feelers, located on the front portion of the head (fig. 1.3). Most of the Crustacea have two pairs of antennae, while the arachnids have none. The more primitive insects, such as the silverfish and cockroach, have conspicuous antennae with many similar segments. In many insects, the antennae are greatly modified and often have characteristic shapes that are useful in identification. (See fig. 1.8).

THE INSECT THORAX

The insect thorax, or chest, is the second main body region (fig. 1.3). It is connected to the head by a membranous region, the neck, or *cervix*. The thorax is composed of three segments made up of varying numbers of sclerites, or plates. Each segment bears one pair of legs. The segments are designated prothorax, mesothorax, and metathorax to indicate their position. Wings, when present, are attached to the mesothorax and metathorax, the last two thoracic segments.

The Wings

Insect wings are membranous extensions of the body wall with an upper and lower layer supported by reinforcing structures called *veins*. Wing veins running from the base to the apex, or point, of the wing are called *longitudinal veins*. The *cross veins* run crosswise to the wing and connect the longitudinal veins. The arrangement and number of wing veins (fig. 1.9) offer important characters for identification of insects. Many of the standard entomological textbooks, as Comstock (1950), have a detailed discussion of wing venation.

Insects typically have two pairs of wings, although certain groups, such as the flies, have lost the second pair which remain in rudimentary form as small knobs called *halteres*, or balancers. Insects possessing two pairs of flying wings may use them independently or may have them coupled together as in some of the butterflies. The forewings in certain orders of insects are adapted as wing covers which will be discussed under the Hemiptera, Orthoptera, and Coleoptera.

The Legs

Insect legs may be short and strong for digging or may be lengthened for jumping and walking, but usually the number of main parts will be constant. The leg is divided into a *coxa*, *trochanter*, *femur*, *tibia*, *tarsus*, and *pretarsus*. Figure 1.10 illustrates some of the many types of insect legs. The femur and tibia correspond to the human thigh and shin and the tarsus has a function similar to that of the foot. Some of the tarsal segments may bear pads, or *pulvilli*, which assist the insect in walking on smooth surfaces, such as glass.

INSECT ABDOMEN

The abdomen, or third body region (fig. 1.3), is made up of segments, or joints, which bear the spiracles and the external reproductive organs. The spiracles are the external openings of the respiratory system, and some insects have a pair on each abdominal segment. In most insects the eighth and ninth segments bear the external sex organs used for copulation in the male and the egg-laying device, or *ovipositor*, of the female. Some insects bear a pair of *cerci*, or tail-like appendages on the eleventh segment.

THE INTERNAL STRUCTURE AND PHYSIOLOGY OF INSECTS

Insects possess all major body systems and senses that are found in the higher animals. Insect *physiology* deals with the functioning of the various organs and systems in supporting the life of the insect.

DIGESTIVE SYSTEM

Insects feed on such diverse foods as green leaves, plant juices, wood, and blood. The mouthparts and digestive system are adapted to permit

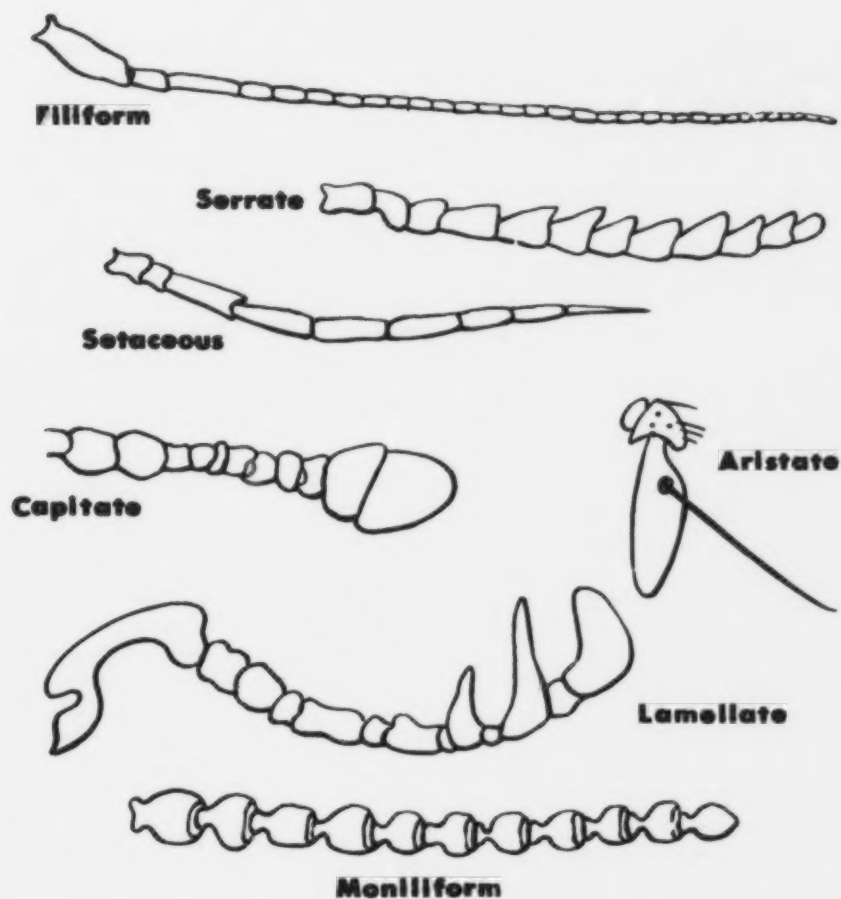


Figure 1.8 Types of insect antennae

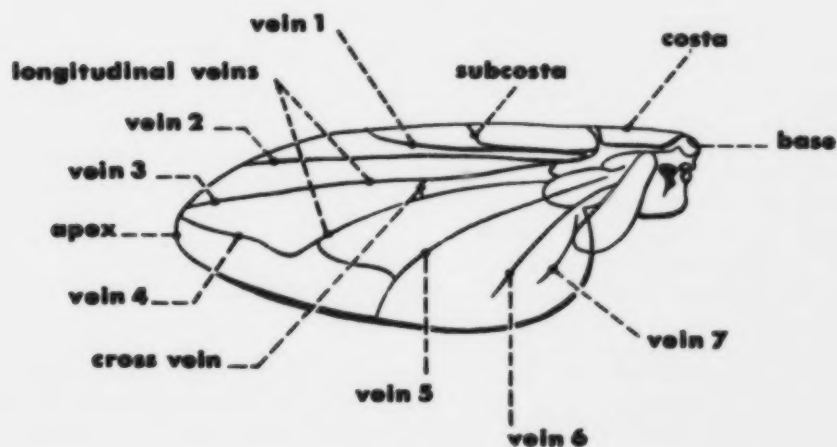
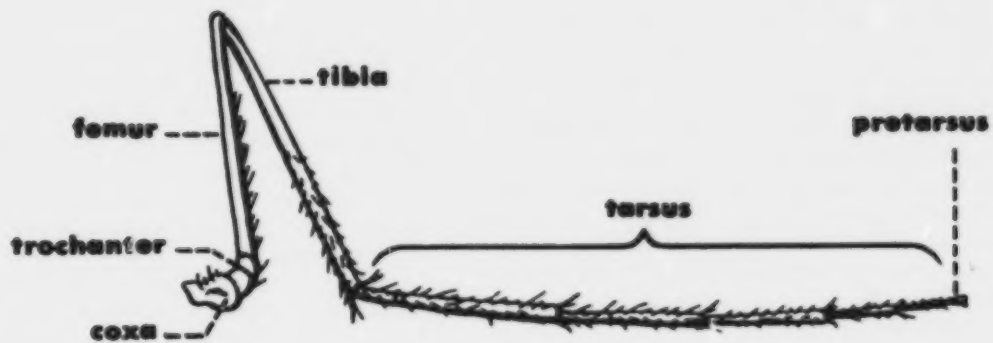


Figure 1.9 Wing venation of a fly



A. Walking



B. Jumping



C. Grasping



D. Clasping



E. Digging

Figure 1.10 Types of insect legs

changing these complex foods into simple carbohydrates, fats, and proteins that will nourish the body cells. The digestive system consists of an alimentary canal which is basically a tube running from the mouth to the anus. It is divided into a foregut, midgut and hindgut corresponding to its embryological origin (fig. 1.11). The food taken into the mouth passes through the **esophagus**, or throat, to the **crop**, an enlarged portion of the foregut that is used for food storage. Some insects possess a **proventriculus**, or gizzard, where food may be ground into finer particles. The food then passes into the **stomach**, or midgut, where digestion takes place. The food then passes out through the **intestine** and **anus**.

Insects living in a dry environment need to conserve all of the water they can. Because of this fact, all possible water is extracted from the liquid mass in the intestines and the feces are discharged as relatively dry pellets. Food may pass through the alimentary canal of the silkworm in 2 or 3 hours, whereas it requires 9 to 33 hours in the cockroach and 2 to 4 days in clothes moth larvae.

Insects may possess **salivary glands** and **gastric caecae** (fig. 1.11) to provide enzymes for food digestion. These glands are sometimes modified to secrete silk as in the spider or to prevent blood from clotting as in the mosquito.

The honey bee has a closed intestine and is unable to excrete solid wastes in its adult stage. Therefore, proteins must be eaten by the larvae whereas the adult bee can feed only upon carbohydrates to produce energy for its living processes. This inability to feed upon protein substances to develop body tissue limits the life span of the adult bee.

EXCRETORY SYSTEM

The excretion of waste from the cells of the insect body is carried out by the blood and the Malpighian tubules. Unwanted chemical compounds are absorbed from the body cells by the blood. These wastes are extracted from the blood by the Malpighian tubules and discharged into the intestine near the junction of the midgut and the hindgut. These tubes vary in number from 2 to 150 or more.

CIRCULATORY SYSTEM

The insect body cavity is filled with a colorless, or greenish-yellow blood that bathes the body tissues, nourishing them and removing waste products. This blood does not bear oxygen and carry off carbon dioxide and serve as a part of the respiratory system as in the higher animals. The blood is not enclosed in blood vessels but circulates freely and seeps into the heart through valves (**ostia**) and is pumped into the head region through the **aorta** (fig. 1.12). The heart beat is regulated by the rate of metabolism and is, therefore, accelerated by a rise in temperature or by muscular activity. The blood is circulated in the legs and antennae by small pulsating organs. Insect blood contains phagocytes that perform their usual function of destroying foreign matter and plugging wounds in the body wall.

NERVOUS SYSTEM

The insect nervous system (fig. 1.13) contains nerve tissue and organs much like those found in the higher animals. The brain lies in the head above the esophagus and is connected to a sub-brain by two nerve cords encircling the esophagus. A double cord extends backward along the ventral surface of the body cavity. Each segment of the thorax has a nerve center or **thoracic ganglion** from which arise many nerves to serve the thoracic region. The more primitive insects have ganglia in each abdominal segment, but these have been reduced in most of the higher insects, as discussed by Snodgrass (1935).

RESPIRATORY SYSTEM

Insects do not have lungs but employ a simple diffusion of air along tracheal tubes to carry oxygen to all parts of the insect body. This system of tubes also acts to carry waste carbon dioxide from the body tissues. Loss of water through this system would be considerable if it were not for the presence of valves in its external openings. These openings, called **spiracles**, (fig. 1.14) are regulated by the presence of carbon dioxide, an excess of

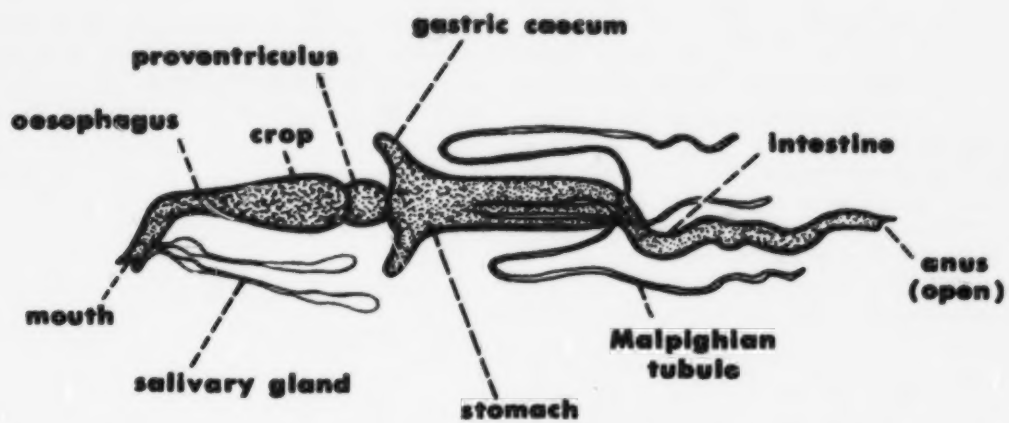


Figure 1.11 Digestive and excretory systems of an insect (diagrammatic)

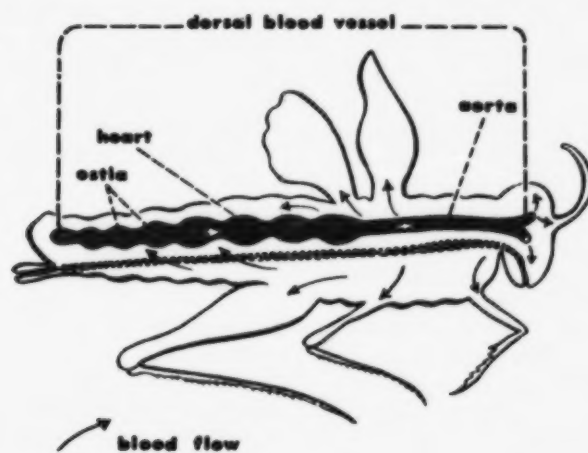


Figure 1.12 Circulatory system (diagrammatic)

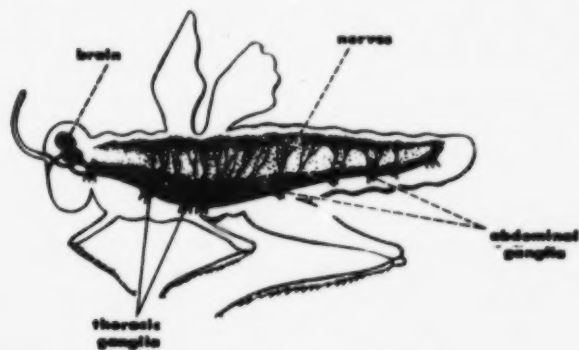


Figure 1.13 Nervous system (diagrammatic)

this gas causing them to open. Air enters the insect body through spiracles into the large tracheal trunks which usually run the length of the body. Many tracheae branch off these main trunks and carry air to the tissues through their finely-branched tracheoles.

Respiratory movements of the insect body alternately compress and expand the large tracheal trunks thereby ventilating the main branches of the respiratory system. Some insects are able to regulate the flow of air, taking it in through anterior spiracles and expelling it through posterior spiracles.

Oxygen requirements of insects are of the order of one mm. of oxygen per gram of body weight per hour varying greatly with species and circumstances. Insects may live for long periods of time in the absence of oxygen. (J. R. Busvine, 1951).

REPRODUCTIVE SYSTEM

Most insects have two sexes which must mate before eggs are produced. Some insects, such as the honey bee, can deposit infertile eggs to produce males (drones) and fertile eggs to produce females, such as the workers and queens. Some insects have only one sex, the female, which can produce young without fertilization by a male, as in the Surinam cockroach. This type of reproduction is called parthenogenesis. These insects are not hermaphrodites as no male organs are present.

The female insect usually produces large numbers of eggs although some species produce very few eggs and others may deposit living larvae. Insects laying eggs are said to be oviparous while those species depositing larvae are said to be viviparous. The tsetse fly, for example, gives birth to larvae already full grown and ready to pupate.

The reproductive organs of the female consist of a pair of ovaries (fig. 1.15) which produce eggs (ova) and pass them into the oviduct and into the vagina where they may be fertilized by male sperm cells stored in the spermatheca. Some species have accessory glands which secrete an adhesive coating or a case for the eggs. A single copulation will supply the female with sperms to fertilize a large number of eggs whether she lays them all at one time or at intervals over a long period.

The male reproductive system (fig. 1.16) consists of a pair of testes in which the sperm cells

are developed, and ducts leading to the penis or ejaculatory organ. The seminal vesicle serves as a reservoir for storing spermatozoa until mating occurs. The accessory glands secrete a liquid substance to serve as a vehicle for the sperm cells.

THE DEVELOPMENT OF INSECTS

The life cycle begins with the fertilization of the egg and is completed when the adult stage is reached. The term "life span" refers to the entire length of life of the insect. Some insects, such as tropical termite queens, may live 15 or 20 years; and the periodical cicada lives for 14 to 17 years. By contrast mayflies may live only a few days as adults although many species spend two or three years in the developing immature stages.

METAMORPHOSIS

Metamorphosis refers to the changes in form or structure of an insect that occur during the period of development. A few primitive insects develop without metamorphosis. The young possess all of the obvious structures of the adult and differ from them merely in size, color, and sexual maturity. The springtails (Collembola) and silverfish (Thysanura) develop without metamorphosis. Both are small wingless insects. The Thysanura grow and molt throughout life so that there is no distinct adult stage.

Insects with GRADUAL or INCOMPLETE METAMORPHOSIS have THREE STAGES in their life history: EGG, NYMPH, and ADULT, as illustrated in figure 1.17. Insects in this group change gradually while going through a succession of molts to become adults. The young resemble the adult insect except for their smaller size and for the absence of wings in wing-bearing species. The young, or nymphs, are immature sexually and may bear wing pads in the latter stages of their development. Some important orders with gradual metamorphosis are:

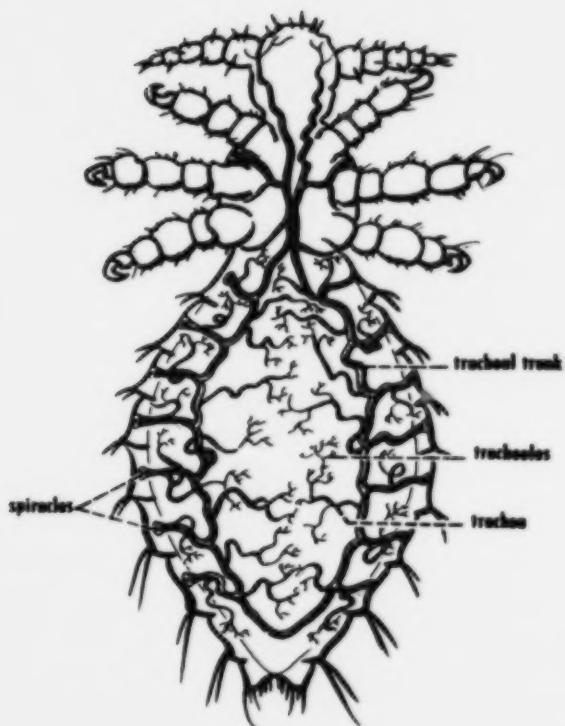


Figure 1.14 Portion of the respiratory system of a louse

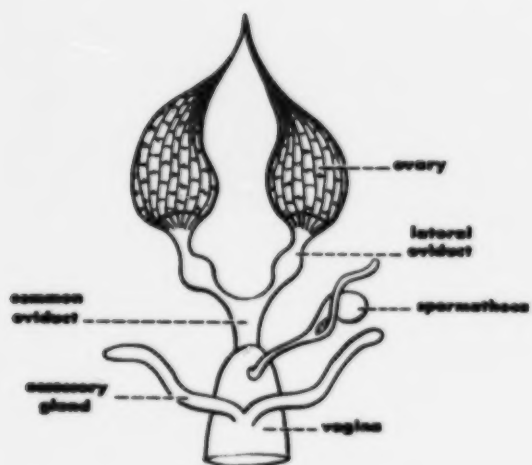


Figure 1.15 Female reproductive system (diagrammatic)

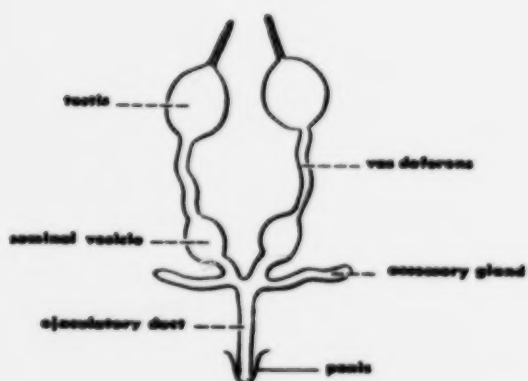


Figure 1.16 Male reproductive system (diagrammatic)

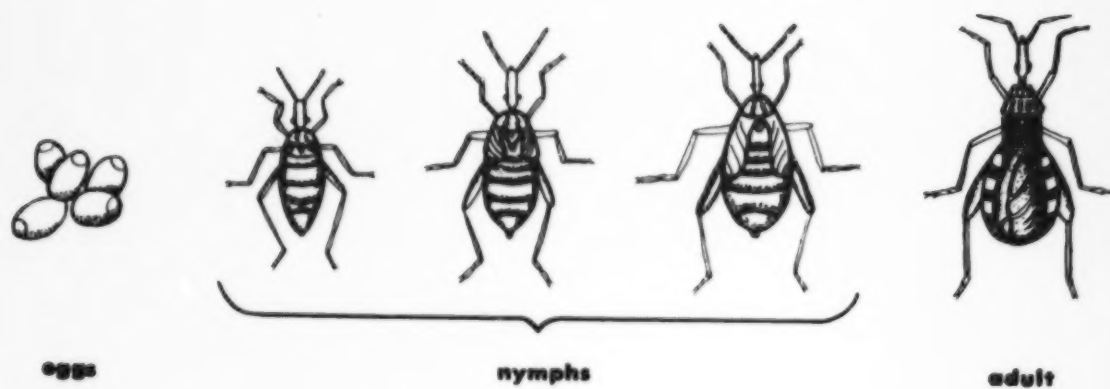


Figure 1.17 Gradual metamorphosis

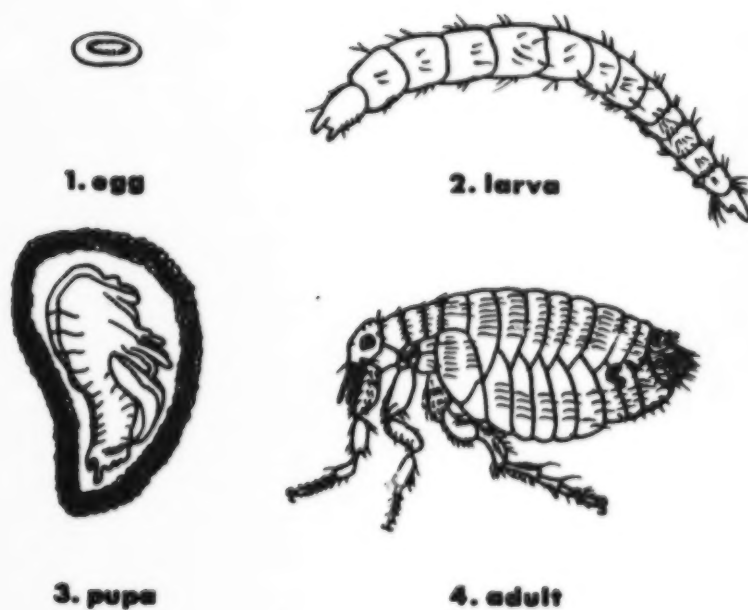


Figure 1.18 Complete metamorphosis

ORTHOPTERA.....cockroaches, grasshoppers, crickets, walking sticks, and mantids.

ANOPLURA.....sucking lice, including the crab and body lice.

HEMIPTERA.....true bugs including the bed bug and kissing bug.

DERMAPTERA.....earwigs.

PSOCOPTERA.....book lice and psocids.

MALLOPHAGA.....biting lice.

Insects with **COMPLETE METAMORPHOSIS** have **FOUR STAGES** in their life history: **EGG**, **LARVA**, **PUPA**, and **ADULT**, as illustrated in figure 1.18. In insects with this type of life history there is a great difference between the immature stages and the adults. Typical larvae are the maggots of flies or the caterpillars of butterflies and moths. The pupal stage is an important evolutionary development during which the simple larva undergoes considerable structural alterations to become the complex adult.

Most of the insects with complete metamorphosis have wings as adults, but some species, such as the fleas, are completely wingless. The wing buds normally appear first in the pupal stage. When the young adult first emerges from the pupal shell, the wings are crumpled and useless. Hydrostatic pressure of the blood within the insect body forces the sac-like wings outward and the two membranes collapse against each other to form the single membranous structure.

There are many orders of insects having complete metamorphosis. Five of these orders of most importance to public health workers are listed below:

DIPTERA.....flies, mosquitoes, midges, and punkies.

SIPHONAPTERA.....fleas.

LEPIDOPTERA.....moths, butterflies, and skippers.

HYMENOPTERA.....ants, bees, and wasps.

COLEOPTERA.....beetles and weevils.

INSECT GROWTH

Small animals have relatively greater surface areas in proportion to their body weight and volume than large ones. This results in increased evaporation of water vapor from the body and requires the development of complex waterproof body coverings. The hard plates in the cuticle also serve as protective armor as well as body support and as the framework for muscles of locomotion.

The development of this armor-like exoskeleton and wings has complicated the growth of insects. The molting process is a means by which an immature insect may shed this protective skeleton, the linings of the respiratory system and of the foregut and hindgut. A molting fluid is produced between the old exoskeleton and the new soft cuticle of the insect. Air or water is swallowed until the body swells, bursting the old cuticle on the dorsal surface in most cases. The insect gradually extracts itself; and a new cuticle hardens on its expanded body, thus accomplishing a stage of growth. The number of molts is small and constant in most species, such as the 3 molts of the house fly; or it may be large and variable as in the 12 or more molts of the American cockroach. For a few hours to a day after molting, the body of an insect may be soft and pale colored, leading some laymen to refer to it as an "albino." During the first day after molting, there is a progressive hardening and coloring of the integument. For this reason, most entomologists allow newly emerged adult insects to remain in rearing containers for 12 to 24 hours before killing and pinning them. For example, if mosquitoes are killed soon after they emerge, their abdomens will shrivel before the integument becomes hardened, making it difficult to identify them.

THE SENSES OF INSECTS

Insects have the same senses that are associated with man. There are the five primary senses of touch, taste, smell, hearing, and sight and other auxiliary senses such as the sense of balance and, possibly, orientation.

SENSE OF TOUCH

Because of its hardened cuticle, the insect's skin is not sensitive to contact. The sense of touch is, therefore, served by sensory hairs borne over most regions of the body. Figure 1.19 compares the sensory hair with an ordinary hair illustrating the nerve which is stimulated if hairs are bent or distorted.

The antennae, or feelers, are important organs of touch. The tarsi and cerci are also sensitive to contact, and insects react very quickly to pressure on these organs.

SENSES OF TASTE AND SMELL

Chemical stimuli resulting from the presence of odors and substances with a taste are usually perceived by small rod-like organs projecting from the body surface. Taste is usually perceived by the mouth, mouthparts, palps, or by the front feet while the sense of smell is localized mainly in the antennae. Palps also bear olfactory organs. The sense of smell is highly developed in insects. It is employed to locate food, find a mate, and to locate suitable places for egg deposition.

SENSE OF HEARING

The organs and degree of sound perception are different among insect groups. Insects do not generally respond to miscellaneous sounds but only to specific noises such as sounds made by the opposite sex. This may be due to discrimination by the insect rather than to a lack of sound perception. Sound waves may be picked up by fine sensory hairs or by special organs such as the auditory drum that appears on the side of the abdomen or the lower part of the front legs. Flies and mosquitoes are believed to hear by means of a cup-like organ on the second antennal segment which responds to sound waves picked up by the rest of the antennae.

SENSE OF SIGHT

The principal organs of sight are the compound eyes and ocelli (fig. 1.4). Fly maggots do not have

eyes but are able to detect the presence of light by means of sensitive tissue underlying the cuticle. This sense is of value to the mature maggot when it leaves its feeding site and burrows into the ground to pupate.

The compound eyes and facets are provided with nerves which transmit stimuli to the brain. Insects can perceive movements very readily, and visual powers usually vary according to the demands made on them by the habits of the insect. Laboratory tests have proved that insects are able to distinguish colors whereas some of the higher animals, such as rats, are color blind. The insect can neither move its eyes nor focus them. However, the praying mantid can rotate its head 180° and is thought to have a good sense of vision.

INSECT BEHAVIOR

There is no proof that insects are able to reason, but many of their complex instinctive actions simulate the results of reasoning. For example, a wasp deposits an egg upon a spider that has been paralyzed by a deft sting in one of the main nerve centers. The spider is then buried in a small cavity in the ground and covered with earth. The wasp then uses a large grain of sand as a hammer to tamp the earth over her nest. Insect behavior appears to be a series of reflex actions or automatic responses to certain stimuli. Most insects feel secure if their feet are touching the ground or some other solid object. Some bugs and beetles turned over on their backs will struggle violently to regain their feet; but their struggles cease if they are given a small object to hold. The honey bee is able to return to its hive by orienting its flight according to the declination of the sun. It performs a dance in the hive which indicates to other worker bees the location of flowers with nectar in relation to the declination of the sun. Despite these complex instinctive actions, it is believed that virtually all insect behavior arises from responses to simple stimuli such as light, heat, gravity, hunger, and smell.

The only animals that can fly are birds, bats, and insects. The ability to fly enables insects to escape many of their enemies, to locate their food, to find their mates, and to populate the earth. Insects such as the grasshopper have extremely strong muscles devoted to flight. The flight

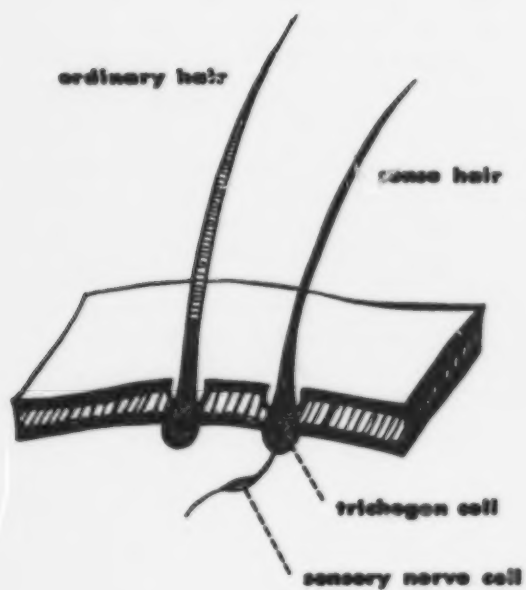


Figure 1.19 Ordinary hair and sense hair (diagrammatic)

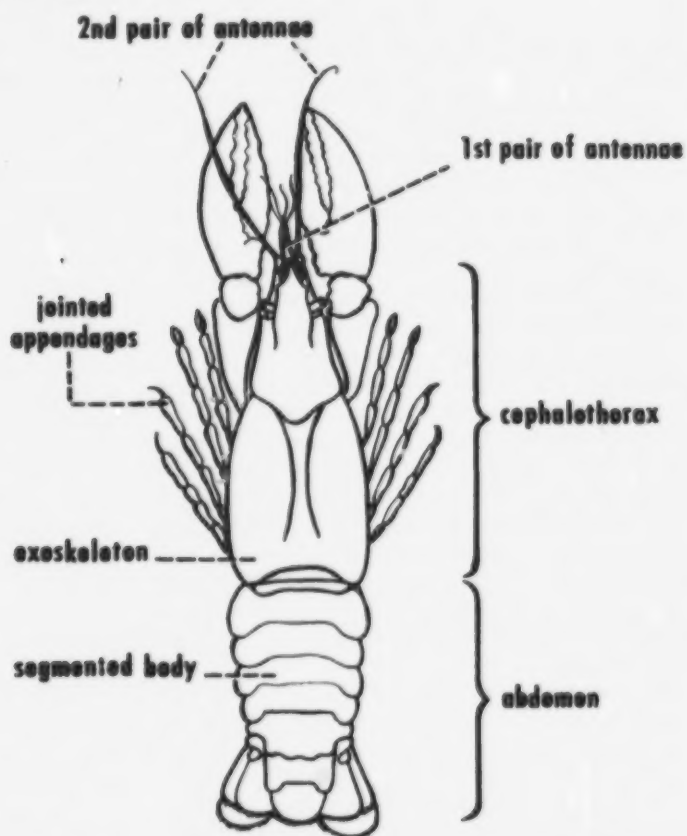


Figure 1.20 Class Crustacea, a crayfish

muscles of the house fly comprise 10 percent of the body weight. They activate the wings indirectly by distortion of the body wall. The wings often vibrate at the rate of about 200 strokes per second. They beat downward and forward and then turn vertically with edge uppermost and move back. Some insects are able to hover and even to fly backward.

CLASSIFICATION OF INSECTS AND RELATED FORMS

It would be impossible to determine the scientific name of any insects without the help of some orderly arrangement or classification. Animals and plants are classified in accordance with a system proposed by the Swedish biologist Linnaeus in *Systema naturae*, 1758. All living things are divided into the plant and animal **KINGDOMS**. The animal kingdom is made up of a number of major divisions, or **PHYLA**. The phylum Chordata contains all animals with a backbone, including man, birds, reptiles, and fish. The phylum Arthropoda contains about 86 percent of all known animal species. Members of this phylum have bodies that are divided into segments, jointed appendages, and an exoskeleton (fig. 1.20). The arthropods are divided into **CLASSES** among which are the Insecta - insects; Crustacea - crabs, shrimps, and others; Chilopoda - centipedes; Diplopoda - millipedes; and Arachnida - ticks, mites, spiders, and others.

The class Insecta (or Hexapoda) includes all true insects. This class comprises a number of smaller groups called **ORDERS**, such as the order Diptera, or flies. Each order is made up of **FAMILIES**, such as the family Culicidae, or mosquitoes. Each family contains one or more **GENERA** such as the genus *Anopheles*, the group of malarial mosquitoes; and each genus has one or more **SPECIES** such as *quadrimaculatus*, the common malarial mosquito of eastern United States. The scientific name of an insect consists of the generic and specific names which are underlined, or italicized. Only the generic name is capitalized, for example, *Anopheles quadrimaculatus* Say or *Homo sapiens* Linnaeus. The word, such as "Say" or "Linnaeus," at the end of a scientific name refers to the first scientist, or **AUTHORITY**, who

described the particular species after the publication of the "*Systema naturae*" by Linnaeus in 1758, the starting date for all scientific names in zoology. A recapitulation of the steps involved in identifying a mosquito or man is given in table 1.3.

It is necessary for public health workers to recognize important insect and arachnid pests. The accurate identification of an insect or arachnid is the key to the literature and all past work on that species. Without correct identification, serious and costly mistakes may be made in planning control operations. Identification of an insect serves the public health worker in the same manner that a correct diagnosis of a disease serves a physician.

THE CLASSES OF ARTHROPODS

THE CLASS CRUSTACEA - Crabs, shrimps, lobsters, sow bugs, and copepods.

The crustaceans are represented by the crab, shrimp, barnacle, sow bug, and many other interesting forms. Crustaceans are important to man as sources of food and as intermediate hosts of certain helminth (worm) infestations, such as the broad fish tapeworm or the Asiatic lung fluke.

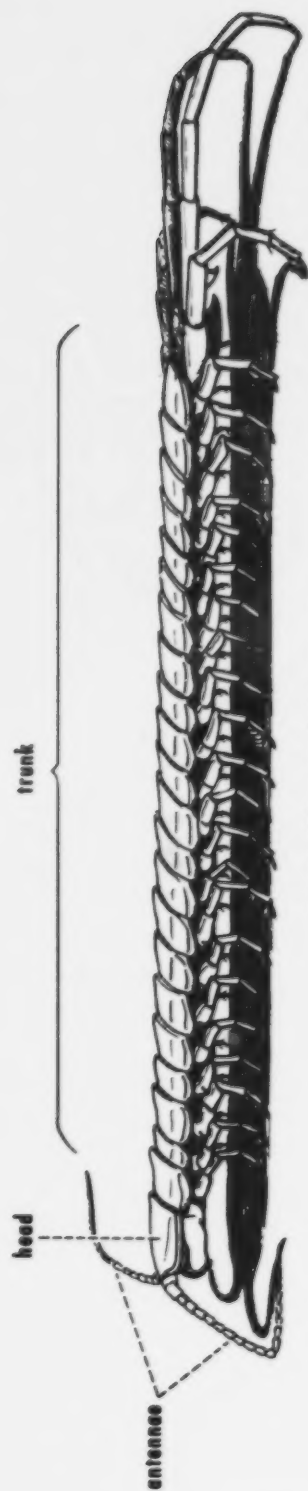
Crustaceans (fig. 1.20) differ from insects in having five or more pairs of legs and two pairs of antennae in typical forms. The head and thorax are combined to form a cephalothorax in lobsters and their allies.

THE CLASSES CHILOPODA AND DIPLOPODA - Centipedes and millipedes.

The centipedes (Chilopoda fig. 1.21) and the millipedes (Diplopoda fig. 1.22) are known as hundred leggers and thousand leggers. The centipede has a head with one pair of antennae and a group of similar segments called the **trunk**. Each trunk segment bears a single pair of legs. Certain species can inject poisonous venom through a pair of poison claws arising from the first trunk segment. This poison is comparable to a bee or wasp sting.

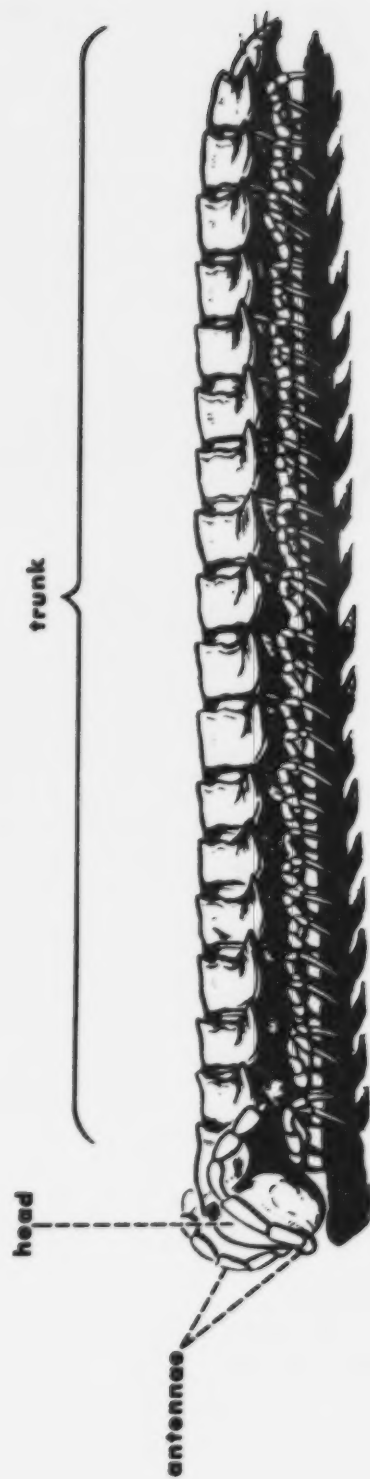
TABLE 1.3 - THE CLASSIFICATION SYSTEM FOR A MOSQUITO AND MAN

Name of Category	Mosquito	Man
KINGDOM	ANIMAL - capable of motion; no chlorophyll.	ANIMAL - capable of motion; no chlorophyll.
PHYLUM	ARTHROPODA - jointed appendages; exoskeleton; dorsal heart; ventral nerve cord; cold blood.	CHORDATA - jointed appendages; endoskeleton; ventral heart; dorsal nerve cord.
CLASS	INSECTA - three pairs of legs; one pair of antennae; wings usually present.	MAMMALIA - mammary glands for suckling young; hair; four-chambered heart; warm blood.
ORDER	DIPTERA - two wings; second pair of wings modified into halteres or balancers; sucking mouthparts; complete metamorphosis.	PRIMATES - Limbs elongate, "hands" and "feet" enlarged, often with a thumb, each of five digits with flattened or cupped nails.
FAMILY (Note family names end in <i>idae</i> in zoology)	Culicidae - The true mosquitoes. Adult with scales on wings, elongate proboscis, wings usually longer than abdomen.	Hominidae - The family of man.
GENUS	<i>Anopheles</i> (note that the generic name of any animal is capitalized and written in italics)	<i>Homo</i> (Latin for man)
SPECIES	<i>quadrimaculatus</i> (note that the species name is always written in small letters and in italics). This species name refers to the four spots in the wing <i>quadri</i> -meaning four, and <i>maculatus</i> -meaning spotted.	<i>sapiens</i> (Latin for learned)
AUTHORITY	Say, 1824	Linnaeus, 1758



1 pair of legs per body segment

Figure 1.31 Class Chilopoda, a centipede



2 pairs of legs on each apparent body segment

Figure 1.22 Class Diplopoda, a millipede

The millipedes have one pair of antennae and two body regions, the head and trunk. They differ from centipedes in that each apparent trunk segment bears two pairs of legs. Millipedes usually do not injure man but may damage some of his plant crops.

THE CLASS ARACHNIDA – Scorpions, spiders, ticks, and mites

The arachnids are common wherever insects occur and are often mistaken for insects. They may be distinguished easily by the fact that they have no antennae and bear four pairs of legs in their adult stages. Figure 1.23 illustrates the fact that the first two body regions (head and thorax) are fused to form a cephalothorax. Some arachnids, such as the mites and ticks, have only one body division. Arachnids have only simple eyes which may be borne in a turret as in the spiders or may lie on the margin of the cephalothorax. Arachnids do not have true jaws, but crush their prey and suck the blood by means of a sucking stomach. They breathe by means of book-lungs, or tubular tracheae, or by both types of respiratory systems.

Spiders are of importance because of their poisonous bites whereas scorpions are capable of inflicting a very painful sting. Ticks and mites are vectors of many important diseases and are second only to insects in public health significance among the arthropods.

THE CLASS INSECTA – True insects.

The insects are the most important members of the phylum Arthropoda. They have one pair of antennae, three pairs of legs, and three body regions: head, thorax, and abdomen (fig. 1.3). Many, but not all, insects have wings. None of the other classes of arthropods have wings.

THE ORDERS OF ARACHNIDS

Order Scorpionida – the scorpions.

Scorpions (fig. 1.23) are arachnids with the abdomen broadly joined to the cephalothorax. The long slender tip of the abdomen bears a stinger enclosing a poisonous gland which is used as a defensive weapon. The large pincer-like palps are borne in front of the first pair of legs. The common ground scorpion does not secrete a deadly poison, but *Centruroides sculpturatus* is a small deadly bark scorpion found in the extreme southwest. It is not unusual for scorpions to enter houses and find harborage in cellars, attics, and other undisturbed places. They may enter shoes during the early morning hours when seeking a dark hideout.

Order Araneida – the spiders.

The spiders are generally harmless and serve a useful purpose in destroying flies, mosquitoes, and other insects. Spiders differ from other arachnids in having the cephalothorax joined to the abdomen by a slender waist and having the abdominal segmentation either indistinct or absent.

The black widow spider, *Latrodectus mactans* (fig. 1.24) is easily recognized by its glossy, black, shoe-button appearance and red or orange hourglass mark on the underside of the abdomen. It is the only spider established in the United States that can kill man. Ragged uneven webs are spun in dark corners of garages, basements, trash heaps, lumber piles, post holes, and other locations. The males are small and harmless and are striped and spotted like the immature females.

Order Acarina – the ticks and mites.

The ticks and mites (fig. 1.25) are in the last group of arachnids to be discussed in this section. They have the head, thorax, and abdomen com-

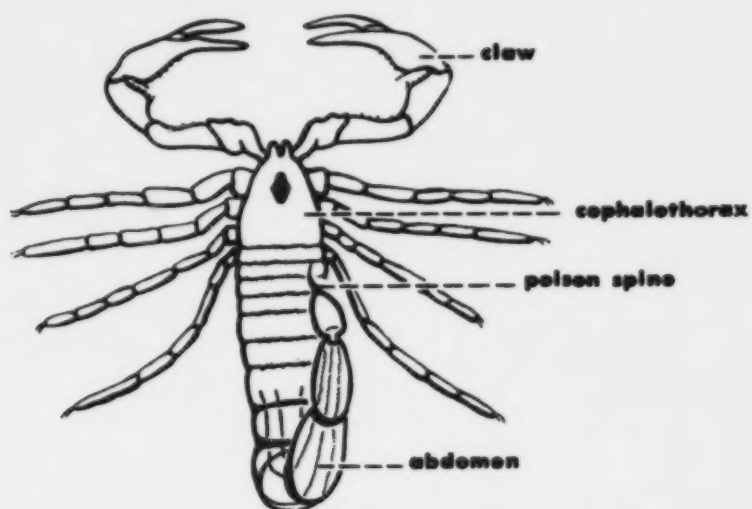


Figure 1.23
Class Arachnida, Order
Scorpionida, a scorpion

Figure 1.24
Class Arachnida, Order Araneida,
a black widow spider

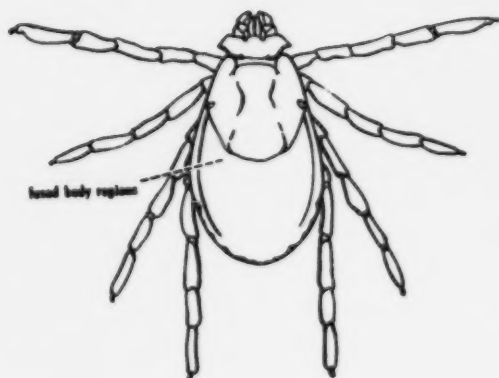
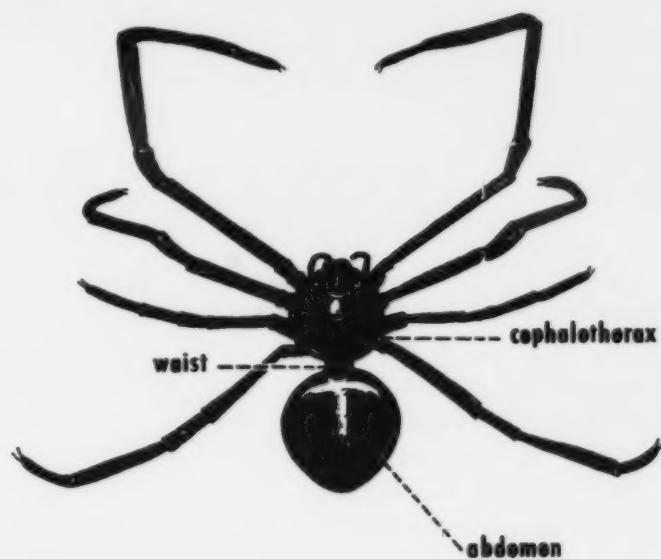


Figure 1.25
Class Arachnida, Order Acarina,
a tick

bined to form a single body region and are often sac-like in form. Most ticks bear a hypostome provided with recurved teeth. The hypostome is a beak used as a piercing-sucking organ in order to obtain the blood of mammals and other hosts. Mites are usually much smaller than ticks and the hypostome, if present, is not armed with teeth. Ticks and mites have six legs in the first, or larval, stage, but the nymphs and adults have four pairs of legs.

THE ORDERS OF INSECTS

All existing insect groups are descended from ancestors which adopted various body types in order to meet their primary needs. The class Insecta is divided into 21 to 30 major groups or orders by various authorities. Members of each order have certain features in common that distinguish them from all other insects. Table 1.4 lists the number of known species in the major orders found in North America north of Mexico. The Coleoptera, or beetles, comprise the largest group; and about two-fifths of the insect species in the world belong to this order. A mere list of the scientific names of known insects would fill a book with two columns to a page and print fine enough for 100 lines in each column and 3,300 pages in length. Therefore, only a few important orders of insects will be mentioned in this chapter. Insects belonging to these orders will be discussed in much greater detail in other chapters in this manual.

INSECTS WITHOUT METAMORPHOSIS

Orders Thysanura and Collembola – the silverfish, firebrats, and springtails

The silverfish (Thysanura) and springtails (Collembola) are of interest chiefly because they have changed probably the least of any of the insects during the development of the insect group. The earliest known fossil insects are springtails from the Devonian Age (300 million years ago). Springtails are often found in buildings, particularly when moisture of potted plants are present. Silverfish may be very destructive of property, eating holes in clothing or starchy materials such as books or wallpaper.

INSECTS WITH GRADUAL METAMORPHOSIS

Order Orthoptera – the cockroaches, grasshoppers, and crickets

The cockroaches, grasshoppers, crickets, praying mantids, and others belong to this group. When wings are present, the forewings are thickened and leathery while the hindwings are folded beneath them like a fan. These primitive insects have chewing mouthparts and develop through a series of nymphal stages by gradual metamorphosis. Some authorities divide this large order into five orders under which classification the cockroaches are placed in the order Blattaria. Only the cockroaches are considered of possible public health importance as mechanical carriers of enteric pathogens. However, other members of the Orthoptera cause great economic losses to agriculture.

Order Dermaptera – the earwigs

The earwigs are rather small, dark-colored insects with a long narrow body and a prominent head bearing relatively short antennae. The males have a pair of prominent curved forceps and the females straight forceps at the tip of the abdomen. The earwigs are largely vegetarian. They are pests in the homes somewhat like cockroaches, but are not guilty of entering the human ear and stinging a person to death as related in some old wives' tales.

Order Psocoptera – the book lice and psocids

The book lice and psocids are very small insects with four wings or are wingless. These insects are of no importance to public health but are often observed in the home and on trees. Book lice are found commonly in bureau drawers, closets, and similar places where they eat starchy materials.

Order Isoptera – the termites

Termites are colonial insects which live in concealed nests or colonies as ants do. Although they are of no importance to health, the sanitarian is frequently asked to determine whether or not termites or ants are present in homes. The subterranean termite lives in the soil and enters the

**TABLE 1.4 – THE NUMBER OF DESCRIBED SPECIES OF IMPORTANT ORDERS
OF INSECTS IN NORTH AMERICA NORTH OF MEXICO***

Order	Common Name	No. of Species
Anoplura	Sucking lice	62
Coleoptera	Beetles, weevils	26,676
Diptera	Flies, mosquitoes, gnats	16,700
Hemiptera	True bugs	8,742
Hymenoptera	Ants, bees, wasps	14,528
Lepidoptera	Butterflies and moths	10,300
Mallophaga	Chewing lice	318
Orthoptera	Grasshoppers, cockroaches, crickets, katydids	1,015
Siphonaptera	Fleas	238
Other Orders		3,815
Total No. of Species		82,394

*Modified from Yearbook of Agriculture, USDA, 1952.

home by means of protective tubes which extend upward on or through the foundation to the wooden structure. Termites may be distinguished from ants by the fact that winged specimens have four wings identical in size and appearance and there is a broad connection between the thorax and abdomen. Winged ants have hindwings smaller than the forewings and different in shape. The abdomen is joined to the thorax by a narrow stalk or waist. Unlike the ants, bees, and wasps in which the workers and soldiers are exclusively females, the termite soldiers and workers are both males and females but have the reproductive organs undeveloped and never mate or lay eggs.

Order Mallophaga – the chewing lice

Chewing lice spend their entire life on their hosts feeding on scales, feathers, hair, or oily secretions from the skin. They cause considerable irritation which affects the health and well-being of most domestic and wild animals and birds. They develop by gradual metamorphosis.

Order Anoplura – the sucking lice

The sucking lice are small, wingless, flattened insects which are blood-sucking parasites of mammals and man. The mouthparts are modified for piercing-sucking and are usually retracted within the head. The eggs, or nits, of human lice and crab lice are attached to the body hairs or to undergarments. They develop by gradual metamorphosis. Lice cause intense irritation. They are of major importance because of their role in carrying typhus and relapsing fevers from person to person.

Order Hemiptera – the true bugs, bed bugs, and kissing bugs

This large order comprises the true bugs, the only insects properly called by that name. The young nymphs go through a series of molts before reaching the adult stage and thus develop through gradual metamorphosis. The adults generally have two pairs of wings of which the basal half or more of the forewings (hemelytra) is thickened and the

remainder is membranous. The hindwings are entirely membranous. Bugs have a scutellum, a triangular body area between the bases of the overlapping forewings. The mouthparts are modified into a beak for piercing and sucking. The bed bug has been an annoying pest of man but transmits no human diseases; the kissing bugs (*Triatominae*) transmit the trypanosomes causing Chagas disease; but most species cause injury by damaging plants or serving as vectors of plant diseases.

INSECTS WITH COMPLETE METAMORPHOSIS

Order Lepidoptera – the moths, skippers, and butterflies

The moths, skippers, and butterflies are distinguished from all other insects by their large, showy wings. The wings are usually completely covered with fine colored scales which rub off as a fine powder when the specimens are handled. Mouthparts are of the sucking type resembling a coiled watch spring beneath the head. The larvae are caterpillars, and metamorphosis is complete. Some species of caterpillars have stinging hairs which can cause severe dermatitis.

Order Coleoptera – the beetles and weevils

The beetles and weevils have four wings in the adult stage. The front pair is heavy and shell-like, serving as wing covers called elytra. The hindwings are membranous and are folded under the elytra. The mouthparts are fitted for chewing, and metamorphosis is complete. This very large order includes many of our worst crop pests.

Order Diptera – the flies, mosquitoes, and gnats

The flies, mosquitoes, gnats, midges, and punkies make up this large order of two-winged insects. A pair of knobs, or halteres, occurs in place of the second pair wings. Some forms, such as the "sheep tick," or ked, lack both wings and halteres. Mouthparts are fitted for sucking or lapping. These insects have complete metamorphosis and the larvae are called maggots or wigglers depending upon the species. Some Diptera are beneficial; many are neutral to man, and many are serious pests and vectors of disease.

Order Siphonaptera – the fleas

Fleas are wingless blood-sucking parasites of birds and mammals. They are very small in size and the body is compressed laterally so that they are quite narrow from side to side. The head bears piercing-sucking mouthparts and antennae and may, or may not, bear a pair of eyes. The legs are well developed and fitted for jumping. Many species have black combs, or ctenidia, on the thorax and head. Fleas have complete metamorphosis with four life stages: the egg, worm-like larva, pupa in a silken cocoon, and adult.

Order Hymenoptera – the ants, bees, and wasps

Ants, bees, wasps, saw flies, and others make up this order which ranks third in size in the class Insecta. Hymenoptera are distinguished from most other insects by their four small membranous wings with few veins. The hindwings are smaller than the forewings. The mouthparts are suited for chewing or lapping. Many species have the apparent first segment of the abdomen reduced to a slender waist as in the ants. The females often have a sting at the end of the abdomen. Metamorphosis is complete.

INSECT IDENTIFICATION

It is not possible to provide keys for identifying insects to species in this chapter as the complete classification of insects is quite complicated and requires many volumes. Certain of the more important insect species may be identified by the use of keys in other chapters of this manual.

Many characters are used to identify an insect to order, family, genus, and species. It is necessary to examine the structure of the antennae, wings, legs, and mouthparts. Frequently minute details, such as certain body hairs, or scales, are important. Therefore, the specimens must be kept in good condition and good microscopes provided for identification. Most large insects may be identified with a hand lens or low power dissecting microscope, whereas the more minute species require use of a compound microscope.

Two types of insect identification keys are used in this manual. The pictorial keys are well illustrated and are very useful for beginners. They

are useful tools for learning the important characters by which insects and arachnids are identified. The other type of key is a couplet key, or dichotomous key. Table 1.5 is a simplified couplet key used for the identification of common classes and orders of arthropods. The student starts with couplet 1 which gives him two choices — in this case the numbers of pairs of legs. When one of the two statements is accepted as applying to the specimen, the number at the end of the statement is noted. The student then proceeds to the couplet bearing that number and again has a choice of two statements concerning his specimen. The above procedure is continued until the correct order of the insect is determined.

The more detailed keys used by advanced workers are similar to the couplet key provided, but they are more detailed and difficult. Insect identification requires the services of trained specialists and most specimens received should be forwarded to a recognized entomologist for determination. However, the sanitarian would do well to familiarize himself with the insect identification method in order that he may identify the most important species in his community. Many workers have small reference collections including all the important insect species in their own localities. They may find assistance in this interesting project by consulting State health departments and State entomologists.

TABLE 1.5

KEY TO SOME COMMON CLASSES AND ORDERS OF ARTHROPODA

Ralph C. Barnes and Harry D. Pratt

1. With three to nine pairs of legs 2
 With ten or more pairs of legs 22
2. With three pairs of legs; antennae present (Class Insecta) . . 3
 With four or more pairs of legs; antennae absent 19
3. With well-developed wings (shell-like wing covers of beetles, earwigs, and cockroaches represent a pair of wings). 4
 Wings absent or rudimentary 11
4. With one pair of membranous wings (flies and mosquitoes). ORDER DIPTERA
 With two pairs of wings (When front wings are modified as shell-like or leathery wing covers, a second pair may be assumed to be present) 5
5. Mouthparts adapted for sucking, consisting of an elongate proboscis 6
 *Mouthparts adapted for biting and chewing 7
6. Wings large, densely covered with scales; proboscis coiled up under head when not in use (moths and butterflies) ORDER LEPIDOPTERA
 Wings relatively small, folded tightly against abdomen, not covered with scales; proboscis directed backward between front legs when not in use (assassin bugs, plant bugs, leafhoppers, kissing bugs, etc.) ORDER HEMIPTERA
7. Both pairs of wings membranous and similar in structure, though they may differ in size 8
 Front pair of wings shell-like or leathery, serving as covers for the second pair 9
8. Both pairs of wings similar in form and size, long and narrow, laid flat over abdomen when at rest (winged termites) ORDER ISOPTERA
 Hind wings much smaller than front wings (wasps, winged ants, etc.) ORDER HYMENOPTERA
9. Front wings horny or leathery without distinct veins, meeting in a straight line down the middle 10
 Front wings leathery or paper-like with a network of veins, usually overlapping at the middle (cockroaches, grasshoppers, and crickets) ORDER ORTHOPTERA
10. Abdomen bearing a pair of prominent cerci having the appearance of forceps; wings considerably shorter than abdomen (earwigs) ORDER DERMAPTERA
 Abdomen without a pair of prominent cerci; wings usually hard and shell-like, covering abdomen (beetles) ORDER COLEOPTERA
11. Abdomen with three elongate, tail-like appendages at tip; body usually covered with scales (silverfish and firebrats) ORDER THYSANURA
 Abdomen without three long tail-like appendages; body not covered with scales 12

*The mouthparts of bees are adapted for both chewing and sucking.

12. Abdomen strongly constricted at point of junction with thorax;
with long running legs and prominent antennae (wingless ants) ORDER HYMENOPTERA
Abdomen not constricted at point of junction with thorax 13
13. With a prominent pair of forceps at tip of abdomen (earwigs) ORDER DERMAPTERA
Without forceps at tip of abdomen 14
14. Body strongly flattened from side to side; antennae small,
fitted into grooves in side of head (fleas) ORDER SIPHONAPTERA
Body not flattened from side to side; antennae projecting
from side of head 15
15. Small to very small white or gray insects (usually less than
¼ inch long); legs short and stout 16
Larger dark brown, red or black insects; legs long and slender 18
16. Antennae of 9 or more segments; tarsi consisting of 4 or 5
segments (termites) ORDER ISOPTERA
Antennae with not more than 5 segments; tarsi consisting of
1 or 2 segments 17
17. Head broad, rounded in front; tarsi usually with two claws –
External parasites mainly of birds, sometimes of mammals
(chewing lice) ORDER MALLOPHAGA
Head narrow; tarsi with a single long claw adapted for
clasping hairs – External parasites of mammals (sucking lice) ORDER ANOPLURA
18. Antennae consisting of 4 segments; mouthparts tubular fitted
for piercing and sucking; very flat, dark reddish-brown insects
(bed bugs) ORDER HEMIPTERA
Antennae long, consisting of many similar segments; mouthparts
formed for biting and chewing (cockroaches) ORDER ORTHOPTERA
19. With four pairs of legs; antennae absent; usually terrestrial (Class Arachnida) . . 20
With five or more pairs of legs or swimmerets; one or two pairs
or antennae present; usually aquatic (crabs, crayfish, shrimp,
lobsters, and copepods) (Class Crustacea)
20. Body round or oval, usually consisting of a single sac-like
region (mites and ticks) ORDER ACARINA
Body divided into two distinct regions, a combined head-thorax
(cephalothorax) and an abdomen 21
21. Abdomen joined to cephalothorax by a slender waist;
body segmentation indistinct or absent (spiders) ORDER ARANEIDA
Abdomen broadly joined to cephalothorax, body distinctly
segmented, with a long slender tail (scorpions) ORDER SCORPIONIDA
22. Body segments each with only one pair of legs (centipedes) (Class Chilopoda)
Most body segments with two pairs of legs (millipedes) (Class Diplopoda)

SELECTED REFERENCES

A few references have been selected to assist the health worker who may wish to obtain more information on insects than can be found in this manual. Some of these references may be purchased but most of them are available in public libraries.

More specific references are provided at the end of each chapter of the manual. The amount of facts in any branch of modern science is enormous. However, insects are important in our lives and a small amount of study will bring greater understanding and appreciation of our insect problem. This manual provides a starting point in the study of insects of public health importance and their control.

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SUGGESTED AUDIOVISUAL AIDS

The following are available on free short-term loan within the United States. Please indicate exact dates that films are to be used and allow ample time for shipment. Requests should be addressed to:

The Communicable Disease Center
U. S. Public Health Service
Atlanta 22, Georgia

Arthropods of public health importance. Filmstrip, USPHS, CDC, 1954, 42 frames, color, with 16-inch disc, 33 1/3 rpm. 7 minutes. Sound.

Introduction to the insects and their allies. Filmstrip, USPHS, CDC, 1958, color, with 16-inch disc, 33 1/3 rpm. Sound.

Collection and shipment of insects. Filmstrip, USPHS, CDC, 1957, 70 frames, color, 9½ minutes. Sound.

Life cycle of *Diphyllbothrium latum*. Motion picture, USPHS, CDC, 1950, black and white, sound, 16 mm. 17 minutes.

In addition, single copies of the following films are available for CDC-State Health Department-sponsored courses from the Insect and Rodent Control Training Section, Training Branch, Communicable Disease Center, Atlanta 22, Georgia.

THE DEADLY FEMALE. Motion picture, black and white, sound, 16 mm. 10 minutes, Van Beuren Production.

THE RIVAL WORLD. Motion picture, color, sound, 16 mm. 35 minutes. Also available on loan from Shell Oil Company, New York Film Library, 160-07 Northern Boulevard, Flushing 58, New York.